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ABSTRACT

Implementing exportable instructional systems has always been a problem for instructional developers. Even the best instructional systems lose effectiveness when they are poorly implemented. Researchers have focused their efforts on creating mechanisms to help developers and managers improve and control implementation. However, most of these efforts do not address long-term effects, or take into account how teachers feel and react during the implementation process. This study presents the Dynamic Implementation Seeking Equilibrium (DISE) model, a nonlinear model of implementation for teacher-mediated instructional systems to measure rate of implementation over time. The DISE model's main independent variable, the exportability control factor (ECF) is an intrinsic quality of teacher-mediated instructional systems. ECF is defined as the amount of instructions, support resources, schedules of activities, and accountability methods embedded in the instructional system to delineate or control teachers' actions so they use the system according to the developers' original intent. The DISE model predicts four distinct scenarios: extinction, stable low implementation, stable high implementation, and unstable implementation with catastrophic change. Beyond the implications for the implementation of teacher-mediated instructional systems, this model offers an example of how some of the concepts, techniques, and methodologies of nonlinear dynamics can be applied to the field of instructional systems development. (Contains 21 references.) (Author/AEF)

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Dynamic Implementation Seeking Equilibrium Model

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Abstract

Implementing exportable instructional systems has always been a problem for instructional developers. Even the best instructional systems lose effectiveness when they are poorly implemented. Researchers have focused their efforts on creating mechanisms to help developers and managers improve and control implementation. However, most of these efforts do not address long-term effects, or take into account how teachers feel and react during the implementation process. This study presents the Dynamic Implementation Seeking Equilibrium (DISE) model, a nonlinear model of implementation for teacher-mediated instructional systems to measure rate of implementation over time. The DISE model's main independent variable, the exportability control factor (ECF), is an intrinsic quality of teacher-mediated instructional systems. ECF is defined as the amount of instructions, support resources, schedules of activities, and accountability methods embedded in the instructional system to delineate or control teachers' actions so they use the system according to the developers' original intent. The DISE model predicts four distinct scenarios: extinction, stable low implementation, stable high implementation, and unstable implementation with catastrophic change. Beyond the implications for the implementation of teacher-mediated instructional systems, this model offers an example of how some of the concepts, techniques, and methodologies of nonlinear dynamics can be applied to the field of instructional systems development.

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Dynamic Implementation Seeking Equilibrium Model

The primary purpose of the Dynamic Implementation Seeking Equilibrium (DISE) model is to represent the process of implementation of teacher-mediated instructional systems through time, or, in other words, how much of a given instructional system we can expect teachers to actually use consistently over time.

General Characteristics of the DISE Model

The DISE model is . . .	*instead of . . .*
Descriptive	Prescriptive
Dynamic	Static
Explanatory	Evaluative
Predictive	Reactionary
Generalizable	Interventionist

The DISE model has the following general characteristics:

1. *Descriptive*: Descriptive theories show the effects that occur when a given class of causal events happen, or the sequence in which certain events take place. These types of theories do not favor one set of outcomes over another; they do not prescribe how to improve or modify a situation. The DISE model describes different scenarios of how teachers implement teacher-mediated instructional systems given a set of causal relationships. It does not evaluate one scenario to be preferable to the others, nor does it suggest how to increase or improve implementation.

2. *Dynamic*: Dynamic models are those which take the time variable into consideration as opposed to static models which give one-shot pictures of the environment or assume that the value of variables does not change over time. The variables in the DISE model are subscripted with the time variable. Their values change through time.

3. *Explanatory*: Explanatory models, a special kind of descriptive model, attempt to identify all relevant components of a system and their relationships, to explain the systemic behavior of the whole. The DISE model attempts to satisfy these requirements by analytically identifying the relevant components of the process of implementation and by representing the systemic behavior of this process with two different representational systems: one mathematical, the other schematical.

4. *Predictive*: Predictive models have the potential to describe, to some degree, a future state of the system under scrutiny, given certain present values. The DISE model can be used to predict future rates of implementation of teacher-mediated instructional systems (the dependent variable) by estimating the present values of the independent variables.

5. *Generalizable*: Generalizable theories apply to any situation within the model's scope. This characteristic is a matter of degree and limited by the scope of the theory under development. The DISE model has been

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successfully applied to a variety of teacher-mediated instructional systems. However, further research is necessary to ascertain the degree of generalizability of the model.

Roles of Those Involved in the Implementation Process

Before being able to delimit the scope of this study clearly, it is necessary to define the roles of all the participants in the implementation process. These roles will help delimit the scope of the model in the next section.

Developers. A class of instructional designers who generate explicit objectives, validated tests, and materials that are instructional and replicable (*materials developers* according to Burkman, 1987) and whose aim is to have a direct influence on the behavior of individual learners. However, in the context of the DISE model, these developers produce information for a cluster of learners who meet at a specified time, led by a teacher who controls what occurs in the classroom (*micro-instructional designers* according to Burkman, 1987).

Teachers. Those potential adopters of developers' instructional innovations who actually use these instructional materials, leading a group of learners to achieve a certain learning outcome. Teachers are ultimately in charge of deciding what, when, and how to implement the new instructional system. This role is defined in a broad, generic sense referring to the person(s) mediating the instruction; they could be teachers in traditional classroom settings, professors, instructors, trainers, tutors, etc. Also, depending on the scale at which the instructional system is being analyzed, the role of teacher could refer to an individual teacher, or an aggregate of teachers, such as a department, a school, a military or industrial training unit, or an entire school district.

Learners. Those potential adopters who are the ultimate audience and target of the instructional system. Learners should benefit from the instructional system by obtaining new knowledge or skills according to the system's learning outcomes.

Master trainers. Some instructional systems require teachers undergo some sort of initial training or certification training before they are qualified or certified to start teaching those particular instructional systems. Those teachers who teach this type of certification training to other teachers are called in this study master trainers. Their role is important because, even though developers may have included detail instructions on how to "correctly" deliver the instructional system's initial training, it still is their prerogative to deliver this training according to their own interpretations.

Scope Delimitation

The primary purpose of the DISE model is to represent the process of implementation of teacher-mediated instructional systems through time, or, in other words, how much of a given instructional system we can expect teachers to actually use consistently over time. This purpose statement implies two scope limitations about the kind of instructional system under scrutiny: (a) The instructional system has to be exported, and (b) it has to be teacher-mediated.

Exportability means that the instructional system is designed to be used by a group of teachers different from those developers who created the system. To make an instructional system exportable, developers purposefully create devices to communicate their idea of how the system should be used to those teachers who will implement the system. This signifies that implementation starts once developers and change agents in charge of training teachers and promoting the adoption of the innovation leave the scene and teachers are not under the direct influence of those who created or promoted the instructional system.

Teacher-mediated instructional systems require a teacher to present the content to the learner. Teacher-mediated instructional systems pose a special problem for developers. Developers must not only arrange the content for learners, but also guide the teachers' actions to present this content appropriately. To do this, developers create a schema of the instructional environment, delineating interactions, schedules, activities, etc. Teachers also have a special challenge when using teacher-mediated instructional systems; they have to not only understand the content, but also interpret and implement the developers' wishes on how to present the content to learners.

For example, a self-study workbook is exportable but not teacher-mediated, so it is outside the scope of this study. On the other hand, an instructor's manual for a class that teaches word-processing is both exportable and teacher-mediated, so it would be subject to the analysis of this model.

Identified Assumptions

In this section I discuss the necessary assumptions which I have been able to identify. I will explain each assumption. These assumptions are necessary to guide the modeling process while building the DISE model. Because they are assumed, these propositions are accepted as valid; however, their validity should be tested in future research efforts.

Teachers seek equilibrium. This assumption is based on experience, observation, and reflection upon human nature. People in general strive to find equilibrium in their lives. Just as physical systems tend toward a state of equilibrium, teachers seem to have a psychological tendency to seek after a state of equilibrium in their teaching practices. Teachers in particular seek to teach in a personal, uniform way. When teachers change the way they teach, they do so in order to improve their teaching, to polish their techniques, to find better examples and explanations. Those practices that work they keep and use the next time. Those that do not, they change, seeking better ones. All these changes are done cautiously and consciously as they seek to achieve a state of equilibrium where they feel satisfied with the learning taking place in their classes. Granted, this state is elusive and ill defined, but can be observed when a teacher teaches certain contents the same as in previous experiences. The DISE model assumes that teachers seek this state of equilibrium, and when they do not achieve it, they feel increasingly frustrated in an unstable, ever-changing environment.

Exogenous changes, such as having to implement a new instructional system, are disruptive to this equilibrium. Teachers seek to quickly adopt and adapt the features of the new instructional system and reach a new level of equilibrium. Teachers may only introduce changes to their teaching or are willing to try new things when confronted with new content or problems; however, once they find some set of teaching practices that work for them and their students, they often prefer to maintain them and use them time after time with little or no change.

Constant quality. Because the focus of the study is on implementation, it assumes that the instructional system's quality is constant. In other words, the effectiveness of the instructional system is not under scrutiny.

Neutral value of implementation. The DISE model attempts to avoid the pro-innovation bias (Rogers, 1995, p. 100) by describing the implementation process impartially, without assuming that higher levels of implementation are better, or more desirable, than lower ones. This study considers rejection, partial implementation, high levels of implementation, and anything in between as likely outcomes of the implementation process. Therefore, this study assumes not only that the quality of the instructional system is high and constant, but also that if teachers decide not to implement the instructional system or to implement something else instead, learning outcomes are not affected.

Teacher, not learner implementation. The DISE model analyzes implementing the instructional system from the teacher's point of view, without taking into account what learners choose to do. For example, if the teacher asks learners to complete certain worksheets, this study considers those worksheets implemented even if learners choose not to complete them.

Teachers try their best. This assumption implies that teachers eagerly strive to do their best in deciding what to teach and how to teach, putting the learners' instructional interest first. They do so not just because it is a job, but because they maximize their personal enjoyment when teaching at their best. This assumption removes any second-guessing on the motives for teachers' deciding for or against implementing certain parts of the instructional system. The DISE model does not take into account other types of motives.

Teachers are free implementation agents. Teachers are assumed to be relatively free and independent and can choose how they are going to teach their classes. This assumption recognizes that teachers are influenced by the environment in which they work to make implementation decisions; nevertheless, once the classroom door is closed, teachers are basically free to conduct their class however they want. Academic freedom is one of the most cherished and defended principles of the educational system. Teachers endure many things, even shamefully low remunerations, in order to enjoy academic freedom.

Teachers are creative. One of the reasons many teachers teach is to satisfy personal psychological needs. Chief among these are the needs to feel creative and needed. Of course these needs vary in nature and intensity from individual to individual, but teachers have to satisfy these psychological needs; otherwise, a continuous repressed creativity generates feelings of frustration. In this study, the expression "creativity need" is used as a general way to encompass all the personal psychological needs teachers seek to satisfy by teaching. To satisfy their creativity, teachers experiment in their classes with different teaching techniques and strategies, which should be their own creation, until they feel that their students are "getting it." When teachers are told what to do, even if it is something good for the students' learning, it does not satisfy their creativity. In fact, it may make them feel unneeded, superfluous, that anyone could do it. Some of the ways teachers express their creativity is by lesson planning, developing teaching materials, and solving instructional situations through previous experience and improvisation when necessary.

Teachers feel frustrated when they cannot express their creativity. As a corollary of the previous assumption, it is further assumed that teachers feel frustrated when having to repeatedly repress their creativity by having to implement very controlling or highly prescriptive instructional systems. For example, if the instructional system prescribes every interaction between teachers and learners, it would leave little or no opportunity for teachers to express their creativity. In this hypothetical situation, teachers would have to decide whether to comply with the

instructional system and repress their creative feelings or implement less and make some room to express their own creativity. If teachers find that they have to repress their creativity often, it is assumed that these feelings of repressed creativity, of disequilibrium, of being controlled, will lead to teachers' feeling frustration toward the instructional system.

Transfer of training research applies to teachers too. The DISE model assumes that when teachers mediate the instruction as they implement teacher-mediated instructional systems, they need to transfer the information to their own students. This implies that the transfer of training research findings (Bransford, 1979; Clark & Voogel, 1986; Cronbach & Snow, 1977; Mayer, 1980) apply to this study. The transfer of training research will be used to construct one of the variables of the DISE model.

Developers have a specific implementation schema. The DISE model assumes that developers have specific ideas or a schema of how the instructional system should be implemented. Even though developers may not be fully cognizant of their own implementation schema or may not fully represent it in their design, this schema exists and it corresponds to the way the instructional developers would use their own instructional system if they were teaching. Developers express these ideas not only by arranging the content for learners, but also by guiding teachers' actions to present this content appropriately. To more effectively communicate their schema and increase exportability, instructional developers carefully delineate instructions, provide resources, schedule activities, and create methods of accountability.

This assumption is necessary because the implementation of this schema is equal to 100 percent implementation. If a teacher were able to use the instructional system exactly the same way that the developer would, then this teacher would be perfectly implementing the system.

Perfect implementation is unattainable. An assumed corollary from the previous assumption is that teachers are never quite able to perfectly capture the developers' schema. Because of personal differences, communication problems, and previous experiences, teachers cannot attain 100 percent implementation. This assumption is necessary to set the range of the main independent variable of the DISE model.

This section listed the assumptions I was able to identify as necessary for building the DISE model. The next section defines the variables of the model.

Variables of the Model

Rate of implementation (I). One way to assess implementation in general is to measure the rate of implementation (I). This is the main dependent variable of the DISE model. It shows what percentage of the original instructional system is being used at each point in time. A value close to 1 shows that teachers are implementing almost everything the original developers intended them to do, that most of the instructional system is being utilized. A rate close to 0 shows that teachers are utilizing only a small portion of the original instructional system.

By choosing to measure rates of implementation, instead of, let's say, actual implementation, the DISE model applies to a variety of settings and permits for comparisons among dissimilar instructional systems—the model is generalizable. However, this choice also implies that the model does not specify what parts of the instructional system will be implemented and which ones will be discarded by teachers, but it only states how much will be implemented. For example, two teachers could implement the same instructional system at the same rate but choose to use different parts of the instructional system.

Initial rate of implementation. The initial value of I (I_0) represents the rate of implementation after initial training, just as the instructional developers pull away from the scene—when the transfer of the instructional system actually occurs. If developers do a good job training teachers in using the new instruction, then I_0 would be high. When developers transfer the new instructional system with little or no effort to inform teachers how to use it, the starting implementation value would be low.

Time iterations (t). The subscript ($t, t + 1, t + 2, \ldots, t + n$), introduced in the previous paragraphs, refers to how many times teachers have used the system. Thus, t is an ordinal, discrete variable instead of a real, continuous one. In the present context, this makes sense because teachers are not constantly engaged in the instructional process; instead they engage in it at intervals. Sometimes these intervals are very frequent and regular (every day, or even every shift); other times the intervals are over longer periods of time or irregular (semester, school year, or training cycle). The length of the intervals between one iteration and the next also depends on the scale at which we are analyzing the system (an individual teacher, a department, a school, or an entire school district). In the DISE model, every variable that changes through time will have this subscript.

Complementary activities ($I - I_t$). Another component of teachers' implementation experience is I_t's complement. All the instructional activities teachers perform during one iteration can be thought of as a whole (I). Those activities not prescribed as part of the instructional system which teachers nevertheless purposefully perform, and which yield a perceived positive result, are here called complementary activities ($I - I_t$). It is recognized that

this is a pseudo-variable because it is defined in terms of rate of implementation; meaning that it is defined by what the rate of implementation is not. This factor represents the successful activities teachers implement in the learning situation that do not originate from the instructional system. Another way of looking at this factor is as an expression of teachers' need to fulfill feelings of creativity and usefulness.

Exportability Control Factor (ECF, K, in the equations). As mentioned previously, developers strive to communicate their internal schema of the instructional system. However, without direct contact, all developers can do is to train teachers, specify precise instructions, create resources, dictate schedules, and enforce accountability from teachers; in short, they can develop an exportable instructional system. The aim of these exportability devices is to communicate the developers' intentions of how the instruction should work. The amount and specificity of these exportability devices constitute an intrinsic quality of teacher-mediated instructional systems, hereby called Exportability Control Factor (ECF, in the equations, is represented by the letter K). This name suggests the amount and specificity of control devices contained in the instructional system to ensure its exportability.

This new theoretical construct has a decisive influence on implementation. In fact, if a teacher-mediated instructional system is going to be truly exported, developers cannot have any contact with teachers after they receive the instructional system; developers can only influence implementation by designing the system's ECF (through instructions, support resources, schedules of activities, and accountability methods) and the initial rate of implementation, I_0 (through initial training.) Therefore, ECF is defined as the (a) initial training, (b) instructions, (c) support resources, (d) schedule of activities, and (e) accountability methods embedded in the instructional system to delineate or control teachers' actions so the instructional system is implemented according to the developers' original intent.

For example, the ECF of an instructional system is high if it specifies each step teachers need to take in order to continue. A medium ECF would be a system which gives suggestions, explicit ideas, or a choice of exercises for teachers to pick and use or modify. On the other extreme, an instructional system with a low ECF contains broad suggestions of possible courses of action teachers should take, or visionary statements of the ideal state of affairs with few or no specifics.

1. *Initial training*
2. *Instructions*
3. *Support resources*
4. *Schedule of activities*
5. *Accountability methods*

Transfer Alignment Coefficient (T). Before defining this variable, it is necessary to define two related concepts—expected transfer and elicited transfer.

Expected transfer is the type of transfer (near or far) necessary to effectively transfer different types of learning outcomes (procedural or declarative). For example, the expected transfer for a declarative learning outcome is far transfer. The more conceptual the learning objective, the farther the expected transfer would be; conversely, the more procedural the learning objective, the nearer the expected transfer would be.

Elicited transfer is the type of transfer (near or far) most likely to be achieved by the type of instructional strategy (behavioral or cognitivist) the instructional system prescribes teachers to use for teaching different outcomes. For example, if the instructional system uses cognitive strategies for the teacher to teach, the elicited transfer is far. The more cognitive or constructivist the instructional strategy of the system, the farther the elicited transfer would be; conversely, the more behavioral the instructional strategy, the nearer the elicited transfer would be.

Therefore, *transfer alignment*, T, is the correlation coefficient ($-1 < T < 1$) between the expected and the elicited transfer per learning objective. If the instructional strategies used by the instructional system to teach different types of learning objectives elicit the same type of transfer as would be expected for the type of objective, then the transfer alignment would be strong (close to 1, aligned). If there is no relationship between the chosen instructional strategies and the type of objectives (for example, a uniform behavioral approach is used to teach all sorts of learning objectives), transfer alignment would be null (close to 0, unaligned). If the wrong strategy is used to teach the objectives or to teach the teachers how to teach these objectives (as in the case when the instructional system behaviorally prescribes for instructors how to teach cognitivist strategies to achieve cognitivist outcomes), transfer alignment would be negatively correlated (close to –1, misaligned).

For example, if the instructional system deals with procedural learning outcomes and uses behavioral teaching methods, then teachers only need to achieve near-transfer of the instruction to their learners. The type of learning, teaching methodology, and transfer required are aligned.

On the other hand, if the instructional system deals with declarative and conditional learning outcomes but uses behavioral teaching methods, or the system behaviorally requires teachers to use cognitive methods, then

teachers may only be able to achieve near-transfer of the instruction to the learners. Simultaneously, they must realize that the system is inadequate in achieving the level of far-transfer required to meet the declarative and conditional learning outcomes. There is a misalignment between the type of learning, teaching methodology, and transfer required.

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Accumulated Frustration (A_t). Whenever teachers increase the rate of implementation of the instructional system from one interaction to the next ($I_{t+1} > I_t$, the rate of implementation now is greater than that during the previous iteration,) they have to sacrifice some of their freedom to use their own complementary activities and repress their creativity. This repressed creativity generates frustration, which accumulates throughout the implementation process. The amount of accumulated frustration is a function of (a) the personal degree of need to be creative, (b) the tolerance to repress this creativity, and (c) the difference in rates of implementation ($I_{t+1} - I_t$) whenever this difference is positive. Only upward changes in the rate of implementation accumulate frustration. When teachers suppress their creativity in order to increase implementation, $(I_{t+1} - I_t) > 0$, frustration accumulates proportionally to this increase. It is assumed that when implementation decreases, $(I_{t+1} - I_t) < 0$, frustration remains static. The definition of this variable is based on the previously stated assumption that teachers feel frustrated when they cannot express their creativity.

The six variables discussed—rate of implementation (I_t), time iterations (t), complementary activities ($1 - I_t$), exportability control factor (ECF, K), transfer alignment (T), and accumulated frustration (A)—are used to model the dynamic process of implementation for teacher-mediated instructional systems. Next, the relationships among these variables are presented to build the DISE model.

Relationships among Variables

Implementation as a function of Exportability Control Factor. By definition, developers design their instructional systems with a certain degree of ECF. This depends on the amount and specificity of initial training, instructions, support resources, schedule of activities, and accountability methods included in the system. The main purpose of ECF is to ensure exportability, to exercise some sort of pressure to implement the instructional system. This pressure influences teachers' decisions on how much of the instructional system to implement, and how much of their own complementary activities to include. This relationship is represented by Equation 1 (All the equations are found in Figure 1 at the end of this document.)

Implementation as a function of previous Implementation. One of the most powerful influences on a teacher's future rate of implementation is that teacher's previous implementation experience with the instructional system itself. Most teachers are constantly monitoring their own teaching practice, looking for those things that work to repeat them in the future, and identifying those things that fail to avoid them. The way they implemented the system the previous time (t) they used it is going to strongly influence the rate of implementation of the system at $t+1$. For example, the way a teacher uses a particular instructional system during today's science class will largely depend on the perceived results of the previous time the teacher used the system, probably the day before during the science period. See Equation 2.

Implementation as a function of previous Complementary Activities. Another force influencing a teacher's future rate of implementation is the effect of previously implemented complementary activities. Those activities not prescribed as part of the instructional system which teachers nevertheless purposefully perform, and which yield a perceived positive result, the complementary activities, tend to lower the rate of implementation the next time teachers use the instructional system. This is represented by Equation 3.

Combining all three relationships. The discussion, so far, posits that future rates of implementation are a function of previous implementation, previous use of complementary activities, and ECF. Now, these three are combined in a logical manner.

As previously stated, the assumption has been made that teachers seek to achieve a state of equilibrium in their teaching practices. Thus, when faced with the implementation of new instructional materials, teachers will seek

to integrate the new materials with their own instructional practices until they achieve a state of equilibrium. They will try different mixes of components of the instructional system and complementary activities until they are satisfied with the new way of teaching. This process takes some time; implementation changes through each iteration until the new equilibrium is achieved. The equilibrium-seeking process is represented by the balancing feedback loop at the top of Figure 2. The delay in the feedback loop represents the t variable, the time interval between each iteration when teachers evaluate their previous implementation experience which influences their next implementation.

Equation 4 is not only the simplest model, but also one that appropriately combines the logical relationships among the factors affecting implementation, including ECF. It shows how I_{t+1} is proportional to the product of I_t and $(1 - I_t)$. Equation 4 should be interpreted as follows: "The rate of implementation for the next time the teacher uses the instructional system depends on the interactions among the exportability control factor of the system, the current rate of implementation, and the current amount of complementary activities." This equation is one commonly referred to in discussions of chaos theory, and it has been applied to model a variety of settings including population growth (May, 1976), population growth of urban areas, economic growth limited by technology, city development limited by existing infrastructure (Cartwright, 1991), and organization of social environments (Marion, 1992).

Graphically, this equation is represented by the balancing loop between I_t and $(1 - I_t)$ and the external influence of ECF diagramed in Figure 2.

The effects of Exportability Control Factor and initial implementation on the final rate of implementation. The mathematical representation of the DISE model, thus far, affords the opportunity to analyze the model's behavior from different perspectives. For example, with Equation 4 the behavior of how I_t changes over time can be analyzed. As mentioned earlier, instructional developers can only influence ECF (directly through instructions, support resources, schedules of activities, and accountability methods) and the initial rate of implementation, I_0 (indirectly through initial training.) However, according to Equation 4, no matter what the value of I_0 is, teachers would tend to implement the instructional system at about the same rate after some time. The long-term implementation of teacher-mediated instructional systems is determined by the system's ECF and not by the initial rate of implementation.

This, however, should not be construed as implying that these teachers would implement the system exactly the same way. The DISE model only shows rates of implementation, but it does not specify what parts of the instructional system will be implemented and which ones will be discarded by teachers. Also, the complementary activities, which in these cases are about one-third of what the three teachers do in their classrooms, are most likely going to be different.

The effect of Time on Exportability Control Factor. As mentioned earlier, ECF is an intrinsic quality of instructional systems and as such it is constant; however, teachers perceive this quality differently depending on several factors. Among these, time is an important factor which changes a teacher's perception of ECF. For example, as teachers gain experience with the instructional system, they become more familiar with it and feel more comfortable with it, thus, their perceived ECF should decrease slightly. In order to account for these changes, the constant ECF (an intrinsic quality of the instructional system) should be changed to a variable ECF (the exportability control of the system as perceived by a teacher at a point in time). The constant ECF could be used as a predictive tool to guide the design process. The variable ECF should be used as an explanatory tool during the actual implementation process. Therefore, to model the changes in perceived ECF, a t subscript should be added to this variable, as shown in Equation 4. Within the context of the DISE model, I call Equation 4 the *implementation equation*.

The effect of Transfer Alignment Coefficient on Exportability Control Factor. Now the attention is turned to the next variable of the DISE model, transfer alignment coefficient, T. What would be the effect of the transfer alignment coefficient on perceived ECF, K_t?

It is theorized that an aligned instructional system, one with a positive transfer alignment coefficient, would have the effect of reducing the perceived ECF because teachers would feel more confident on the instructional soundness of the system. Even highly prescriptive instructional systems, with ECF < 3, would seem less controlling when the system's instructional strategies are aligned with its learning objectives.

Conversely, a misaligned instructional system, one with a negative transfer alignment coefficient, would increase the perceived ECF because teachers would feel confused by not being able to efficiently transfer the instructions found in the system to their teaching situations.

It is further theorized that unaligned instructional systems, transfer alignment coefficients close to zero, would have little or no effect on perceived ECF. This unalignment would just solidify teachers' perceived ECF.

A simple way to model this relationship is to subtract the transfer alignment coefficient from the perceived ECF, $(K_t - T)$. This relationship is shown by Factor 5 in Figure 1.

The effect of Transfer Alignment Coefficient on Complementary Activities. Furthermore, transfer alignment coefficient also has an effect on how teachers evaluate the effect of complementary activities. Positive transfer alignment coefficients would strengthen the influence of previous implementation, I_t, over complementary activities, $(1 - I_t)$ because aligned instructional strategies would be more appealing to continue implementing. Conversely, negative transfer alignment coefficients would strengthen the influence of complementary activities, $(1 - I_t)$, over previous implementation, I_t, because in these situations teachers would feel more justified to continue implementing their own activities.

The DISE model mathematically represents this relationship by dividing the complementary activities factor, $(1 - I_t)$, by $(1 + T/2)$, showing that a positive transfer alignment would lower the pressure to implement complementary activities. This relationship is modeled in Factor 6.

From my limited experience analyzing instructional systems, I suspect that most instructional systems are unaligned (T close to zero) because developers would tend to apply similar instructional strategies, those with which they feel most comfortable, to address different types of learning outcomes. For example, behaviorist instructional developers are likely to apply behaviorist learning strategies for all types of learning outcomes, be they procedural, declarative, or conditional. The same could be suspected of cognitivists and constructivists. I also forward that aligned instructional systems (T close to 1) are more likely to be those systems which have been carefully designed, paying close attention to address learning outcomes with appropriate instructional strategies. This implies that transfer alignment is unlikely to happen accidentally. Hopefully, I propose that misaligned instructional systems (negative T) are rare.

The Effect of Transfer Alignment Coefficient on Implementation. The combined effect of transfer alignment on future implementation can be deduced from the discussions in the previous sections. A positive alignment would have the effect of increasing implementation because teachers would be more likely to achieve the appropriate type of transfer as they teach with the instructional system. Teachers would be willing to implement more of the instructional system because they could see that the system provided an appropriate strategy for them to teach and achieve the desired results. In a way, this positive transfer alignment would have the effect of dampening the frustration of high levels of ECF. A null transfer alignment would have no such effect, and a negative alignment would actually lower implementation of even instructional systems with moderate levels of ECF.

Accumulated Frustration as a function of increases of Implementation. The definition of the accumulated frustration variable stated that when teachers suppress their creativity in order to increase implementation, $(I_{t+1} - I_t) < 0$, frustration accumulates proportionally to this increase. The assumption was made that when implementation decreases, $(I_{t+1} - I_t) < 0$, frustration remains static. To describe this relationship between increases of implementation and accumulated frustration, A_t, the following Equation 8 is proposed.

Exportability Control Factor as a function of Accumulated Frustration. The last relationship to model is the one between ECF and A_t. It has already been mentioned that feelings of frustration, disappointment, dissatisfaction, and dejection may lead to second-order change. Below a certain threshold value, this type of change is unlikely. Above this threshold, change is imminent (Dooley, 1997). This phenomenon has been studied in neuronal patterns (de Bono, 1969) and managers' decision-making processes (aspiration theory; Cyert & March, 1963; Kiesler & Sproull, 1982). Likewise, each teacher has a tolerance threshold value to withstand the accumulated frustration. Below this value, teachers deal with the frustration the best they can, slightly adjusting their perception of ECF, due to the familiarization effect. They keep trying to implement the instructional system, probably changing the implementation mix to avoid having to repress their creativity so much the next time they use the system.

If the instructional system's ECF is not very high, implementation reaches stability before the frustration accumulates beyond the tolerance value. However, if the system's ECF is very high and implementation continues to be unstable, more frustration accumulates with each spike in implementation. Eventually, the accumulated frustration will surpass the tolerance threshold value. At this point, what can teachers do? This situation leads teachers to drastically change the instructional system to a less controlling environment by changing the instructional system's ECF.

What are some of the behaviors teachers exhibit that so drastically change their perceptions of the instructional system? Under the right conditions, teachers might go to extreme measures in order to create a more stable and tolerable environment. Some may disregard whole parts of the instructional system; others may quietly put it aside, lobby to their superiors for the system's dismissal or change, stop reporting to their superiors, or invent excuses for not using the system—claiming it doesn't work or that the students get bored. Some teachers may even quit their jobs in order to escape a controlling, intolerable situation; such cases exemplify the ultimate in non-implementation.

Mathematically, to represent the second-order change relationship between ECF and A_t, with slow changes in ECF, below the threshold value and a drastic change above this value, Thom's cusp catastrophe equation (Thom, 1975; Zeeman, 1976) is adapted, as shown by Equation 9.

As A_t increases, pushed by the upward shifts in implementation (as modeled by Equation 8), K_t diminishes. At first, K_t diminishes very slowly, then as A_t approaches the fold in the curve, K_t diminishes at an increasing rate. When the value of A_t gets to be higher than the value of the right edge of the fold, K_t drastically jumps to the lower part of the curve. This sudden change in ECF represents teachers' decisions to respond to their accumulated frustration by changing the instructional system and transforming it into a less controlling environment. This behavior, modeled by the cusp, is called a catastrophe not because of any negative connotation of the word, but because a small change in the value of the control parameter (A_t) can cause a sudden large change in the value of the independent variable (K_t).

It is important to remember that the catastrophic change only occurs if frustration accumulates beyond the teachers' tolerance threshold level, which only occurs if implementation keeps oscillating in an unstable fashion. This happens when ECF is high and transfer alignment is low, or both. shows the DISE model's behavior when ECF > 3 and transfer alignment is null.

The complete DISE model. is the complete graphical representation of the DISE model. Mathematically, the complete DISE model is Equations 10, 11, and 12 put together in a system of three equations, shown in Equation 13.

The DISE model of implementation for teacher-mediated instructional systems states the following: (a) The rate of implementation is a function of the instructional system's ECF as perceived by teachers, the previously experienced rate of implementation and the complementary activities. (b) This function is a balancing loop which leads to stable rates of implementation. (c) A positive transfer alignment coefficient strengthens the perceived ECF and weakens the effect of complementary activities; in general, it increases rates of implementation. (d) If ECF is high and implementation is unstable, teachers accumulate frustration as they need to repress their creativity when raising the rate of implementation. (e) Below a tolerance threshold value accumulated frustration reinforces the perceived ECF due to familiarization with the instructional system. (d) If implementation remains unstable and frustration accumulates beyond the tolerance point, teachers will drastically change the instructional system to one with a lower ECF.

Implementation Scenarios

The DISE model of implementation for teacher-mediated instructional systems describes five distinct implementation scenarios: (a) extinction, (b) low stable, (c) high stable, (d) unstable with second-order change, and (e) aligned high implementations. Each scenario is discussed next.

Extinction Implementation. When the ECF of the instructional system is very low (between 0 and 1 when transfer alignment is null,) the rate of implementation falls toward 0. Left to themselves, teachers of an instructional system with such a low ECF feel disoriented and unsupported. Teachers cannot find enough instructional support in the system to implement it, so they eventually abandon it. They become confused and uncertain, and at the same time feel pressured to perform their duties. Under these conditions, teachers rapidly abandon the new system and revert back to their old teaching habits, or improvise and create their own solutions, which may or may not be better than the new system but which, at least, provide the much-needed equilibrium the teachers are seeking. I have studied several cases exemplifying this scenario, for example, a case where teachers in an elementary school attempt to implement but quickly abandon a new high-technology classroom program.

This extinction can be correlated with Dooley's (1997) third-order change, where a particular schema survives or dies in a Darwinian, competitive fashion. In other words, teachers compare what they are expected to do against what they have been doing, and decide between one or the other. In this case, the implementation of the instructional system dies and the teachers' complementary activities or the previous "status quo" survive. Notice that this extinction occurs no matter how high the initial rate of implementation (I_0) was; a high I_0 only delays the eventual fate of the implementation.

Stable Low Implementation. The second scenario, when the ECF is between 1 and 2 (null transfer alignment coefficient), can be called Stable Low Implementation. In this case, the instructional system provides enough controls to help teachers try the system on their own and appreciate its virtues. However, the relatively loose control mechanisms eventually let teachers continue using their current, personal instructional methods (fulfilling the individual's need for creativity, recognition, and security). Teachers adopt only those features of the system which are better developed, more closely match their instructional philosophies, and better fill voids in their current repertoire of instructional materials. Under these conditions, the DISE model predicts that teachers will consistently implement only a small percentage of the instructional system (less than half). The model does not predict which

parts of the system they will implement, nor whether different teachers will implement the same parts. A case study essay describing a hypothetical college professor's implementation of a textbook serves as example for this scenario.

Stable High Implementation. When the ECF of the instructional system is moderately high ($2 < ECF < 3$, $T = 0$), the system reaches the Stable High Implementation scenario (and middle right part in Figure 1). In this case, as in the previous one, an increase in the system's ECF achieves an increase in the stable rate of implementation. However, gains in the stable rate of implementation are smaller than in the previous case (the slope of the curve in Figure 1 diminishes from 1 to 0 in this interval). The increased control included in the instructional system affords teachers a higher degree of security, guidance, and comfort to use more features of the system. However, teachers still feel the personal craving to express creativity, so they take up a portion of the available contact time to implement their own strategies, discarding what they consider the weakest parts of the instructional system. The DISE model predicts that for systems with an ECF close to 3, teachers would implement about two-thirds of the original instructional system in a stable fashion. Again, the model does not predict what parts of the system might be implemented, just that more would be implemented than in the two previous scenarios.

In these two stable scenarios, during the first few iterations, the rate of implementation oscillates around the converging value. These oscillations on the rate of implementation can be explained as what Argyris and Schon term first-order learning (1978). First-order learning occurs when agents change their course of action in order to conform to their perceived schema. This means that for this type of change teachers will adjust what they do in order to conform with what they are expected to do. This creates a negative feedback loop (like the balancing loop in) in which actions converge toward the schema. During this process teachers try different aspects of the new instructional system until their actions converge with the new schema. At the end of this process, they would have achieved a new state of equilibrium. This part of the implementation process is what the DISE model attempts to describe by showing how teachers change the rate of implementation (I_t) and the complementary activities (I_{t-1}) with each iteration until they reach equilibrium.

For these three scenarios, ECF_t changes only slightly, if at all, due to increased familiarity with the instructional system. Equation 10 and are sufficient to model these three scenarios.

Unstable Implementation with Catastrophic Change. The next scenario corresponds to instructional systems with high ECF ($3 < ECF < 4$, $T \equiv 0$). It can be called Unstable Implementation with Catastrophic Change (c and right side of Figure 1.) An instructional system with ECF this high imposes so many expectations on teachers that it constrains their freedom. Teachers have to battle an internal conflict between doing what they are told to do and doing what they want to do. The DISE model predicts that the rate of implementation jumps back and forth between high and low values. In general terms, the higher the ECF, the more unpredictable the rate of implementation will be. This unstable implementation does not allow teachers to achieve the equilibrium they are seeking. The situation becomes untenable. Teachers in this situation become increasingly frustrated with the instructional system, and keep trying alternatively to implement the system and to satisfy their creativity until they have had enough and decide to drastically change this intolerable situation. Teachers do so by changing the instructional system to one with a much lower ECF. Once these sudden changes occur, implementation converges to the appropriate lower rate of implementation.

The right side of Figure 1 shows I_t's behavior when $ECF_t > 3$; I_t does not settle to a single value. First, I_t suffers a bifurcation and oscillates between two values. As ECF_t increases, I_t bifurcates again and again until it reaches a chaotic region in which I_t does not settle but oscillates aperiodically within a certain range of values. As pointed out before, c shows the time series graph when $ECF_t = 3.8$. And shows the unstable oscillations with the catastrophic change.

In my research I have documented two case studies exemplifying this scenario. One of them shows how tutors changed a highly prescriptive reading program to a more flexible one. The other one relates the implementation of a series of managerial skills training modules in a business environment.

Aligned High Implementation. The previous implementation scenarios seem to imply that stable rates of implementation cannot be higher than two-thirds. However, these cases assumed unaligned instructional systems ($T \equiv 0$, see b). As has been discussed, the DISE model posits that positive transfer alignment coefficients increase implementation. This is specially true for instructional systems with high ECF. Therefore, a highly aligned, highly prescriptive instructional system could see stable rates of implementation even above 90 percent ($I_t \equiv .90$). Teachers seem to be more willing to implement a prescriptive instructional system and, if needed, even to repress their creativity when the alignment between learning outcomes and instructional strategies is evident. This is depicted in a.

I have encountered two case studies describing the aligned high implementation scenario. One was a highly prescriptive two-day training workshop with very specific learning outcomes and closely aligned instructional

strategies. The other one was a highly structured reading program where some teachers perceived the program's positive transfer alignment and understood its design and were able to maintain implementation at high rates.

Generalized Propositions Derived from the DISE Model

The DISE model has been presented. I have discussed the model's scope, assumptions, variables, relationships, and scenarios. This last section discusses those generalized propositions I have derived from the DISE model. It is important to remember that these propositions only apply to instructional systems within the scope of the DISE model: teacher-mediated instructional systems. These propositions are offered as generalizations derived from the model and suggest guidelines for developers' instructional design efforts. Their validity is subject to future theory testing and theory improvement efforts.

1. *The rate of implementation of a teacher-mediated instructional system is dependent on the perceived amount of exportability controls embedded in the system (ECF) and its transfer alignment coefficient.* The effect of ECF on implementation was demonstrated by the model in and . The effect of transfer alignment on implementation was depicted in . This proposition implies that instructional developers should pay purposeful attention to how they design an instructional system's initial training, instructions, support resources, schedules, and accountability methods to convey the desired ECF and how they align the system's instructional strategies with its learning outcomes, if they want to improve their chances that the systems gets implemented as intended.

2. *Normally, the transfer alignment coefficient is directly related to the rate of implementation.* This proposition posits that it is unlikely for a misaligned instructional system to have high rates of implementation (see). It also implies that instructional systems with stable high rates of implementation are most likely positively aligned.

3. *The final rate of implementation of a teacher-mediated instructional system is not dependent on the initial rate of implementation.* This was clearly shown by where in spite of different initial rates of implementation, the final stable rate of implementation did not change. This proposition suggests that instructional developers should not spend undue efforts personally emphasizing high initial rates of implementation while they are still around, and implementation, strictly speaking, has not yet started. Rather they should concentrate on communicating the correct ECF and on designing highly aligned systems.

4. *The rate of implementation changes through time until it reaches a state of equilibrium.* This proposition was modeled by the outcome of the different scenarios and exemplified with case studies. According to the DISE model, even for very different conditions, the rate of implementation changes until it settles into a state of equilibrium.

5. *The way individual teachers perceive a teacher-mediated instructional system's ECF and transfer alignment can be different enough to greatly affect the rates of implementation over time.* Teachers' perceptions cannot be underestimated nor easily dismissed. Instructional designers should attempt to estimate these perceptions beforehand in order to design the most appropriate ECF and transfer alignment.

6. *After teachers' implementation reaches a state of equilibrium, only significant changes to these teachers' perceived ECF and transfer alignment could change the rate of implementation.* Such was the case of the implementation I found in one of the case studies where a significant change in the way the master trainers taught the certification training communicated very different levels of ECF to the teachers and they changed implementation accordingly.

7. *A teacher-mediated instructional systems with ECF below a certain level (extinction point) eventually will cease to be implemented.* See a. It is important to point out that, according to the DISE model, this outcome would occur no matter what the initial rate of implementation was. Probably, this is the worst-case scenario, because it wastes the most resources. Instructional developers should be careful not to attempt implementing instructional systems which run the risk of suffering extinction.

8. *A teacher-mediated instructional system with ECF above a certain level (unstable point) will be implemented at a unstable, changing rate for a period of time, until teachers significantly alter the instructional system to one with a lower ECF.* I have found a few examples for this proposition (see). I consider this scenario to be the next worst one because when the catastrophic change occurs, all bets are off on how the instructional system will be implemented. Implementation could fall to a low stable rate or even below the extinction point to zero.

9. *Teacher-mediated instructional systems with moderate ECF (between the extinction point and the unstable point) have a non-zero, stable rate of implementation.* Several cases were presented to illustrate these scenarios (see and b). This type of incomplete or partial implementation is the most common implementation outcome for teacher-mediated instructional systems. This conclusion is supported by Rogers' (1995) evidence of how prevalent reinvention of innovations is and by the effect of innovation configurations as modeled by the CBAM model (Hall & Loucks, 1981). Other studies also support the idea that teachers adapt the instructional system and vice versa (Berman & McLaughlin, 1974, 1976; Davis, Stand, Alexander, & Hussain, 1982; Gephart, 1976).

10. *For teacher-mediated instructional systems with moderate ECF (between the extinction point and the unstable point), as ECF increases, the stable rate of implementation also increases but it does so at a diminishing rate.* This is shown by the diminishing slope of the curve in Figure 1 and . The implication of this proposition is that a developer's efforts to increase implementation by increasing the instructional system's ECF will have diminishing returns on the investment. This effect could prompt the developer to keep increasing the level of ECF, to achieve higher rates of implementation, beyond the unstable point. This could generate an unfortunate outcome.

11. *Initial training can be used to communicate the desired ECF and transfer alignment to teachers.* Developers should pay close attention to this important component of ECF. Nevertheless, unless they are planning to personally perform this initial training themselves, if developers have to rely on master trainers to deliver the initial training, then the initial training itself is subject to the implementation dynamics of the DISE model.

This presentation has described the DISE model in an analytical, step-by-step fashion. The DISE model presents a theory of how teacher-mediated instructional systems might be implemented over time. The model's scope and assumptions were carefully delimited and identified. The variables of the model were defined. The model was then represented using mathematical, graphical, and narrative representational systems, building the model's relationships. Five distinct implementation scenarios were described. Finally, several generalized propositions derived from the model were discussed, suggesting some development guidelines for instructional developers.

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